US005867071A

United States Patent [19]

Chethik

[11] **Patent Number: 5,867,071**

[45] **Date of Patent: Feb. 2, 1999**

[54] **HIGH POWER TRANSMITTER EMPLOYING A HIGH POWER QAM MODULATOR**

[75] Inventor: **Frank Chethik**, Palo Alto, Calif.

[73] Assignee: **Lockheed Martin Aerospace Corp.**, Bethesda, Md.

[21] Appl. No.: **911,677**

[22] Filed: **Aug. 15, 1997**

[51] **Int. Cl.**[6] **H03C 3/00**; H04L 27/36

[52] **U.S. Cl.** **332/103**; 375/264; 375/308

[58] **Field of Search** 332/103–105; 375/261–265, 279–284, 308; 455/103–105, 129; 331/56, 75

[56] **References Cited**

U.S. PATENT DOCUMENTS

5,237,292 8/1993 Chethik 332/103

5,463,355 10/1995 Halloran 332/103

Primary Examiner—David Mis

Attorney, Agent, or Firm—Kenneth W. Float

[57] **ABSTRACT**

A high power RF transmitter that uses high power modulators that perform quadrature amplitude modulation (QAM) on a carrier signal after power amplification that is performed in the RF carrier source. The present invention transposes the locations of the modulators and power amplifier, and thus directly modulates a high power carrier signal. An RF carrier source generates a high power RF carrier signal that is split by a power splitter. A lookup table containing 2^B words by K bits receives transmit data and mapping data and generates K-tuple modulating data. A plurality of phase key modulators are respectively coupled to outputs of the power splitter and to the lookup table and phase key modulate each of the signal components of the carrier signal using the K-tuple modulating data. A power combiner is coupled to outputs of the phase key modulators for outputting a high power QAM constellation from the transmitter.

8 Claims, 3 Drawing Sheets

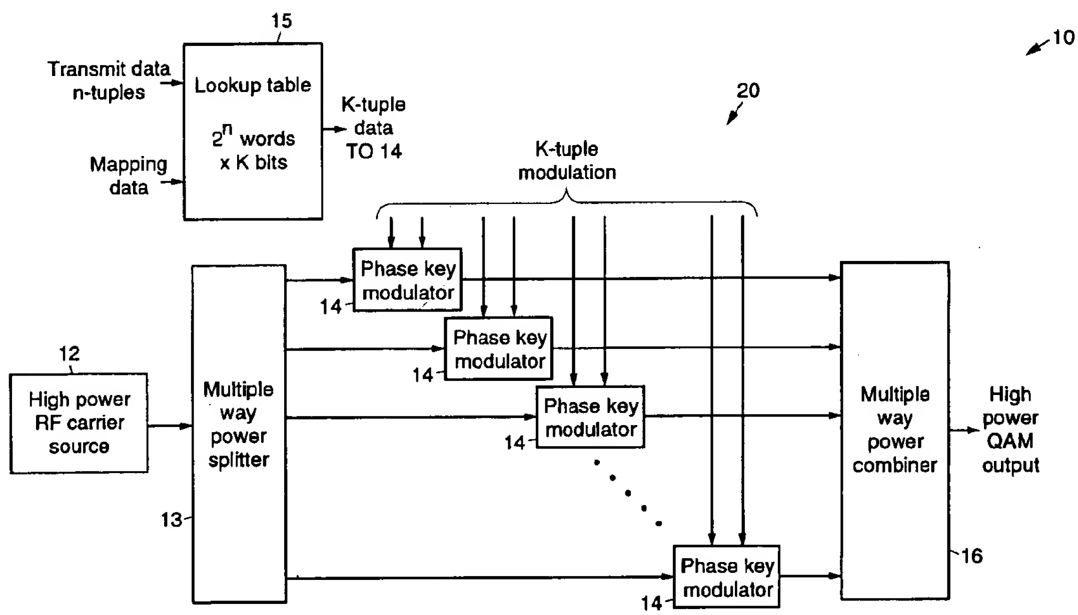


Fig. 1

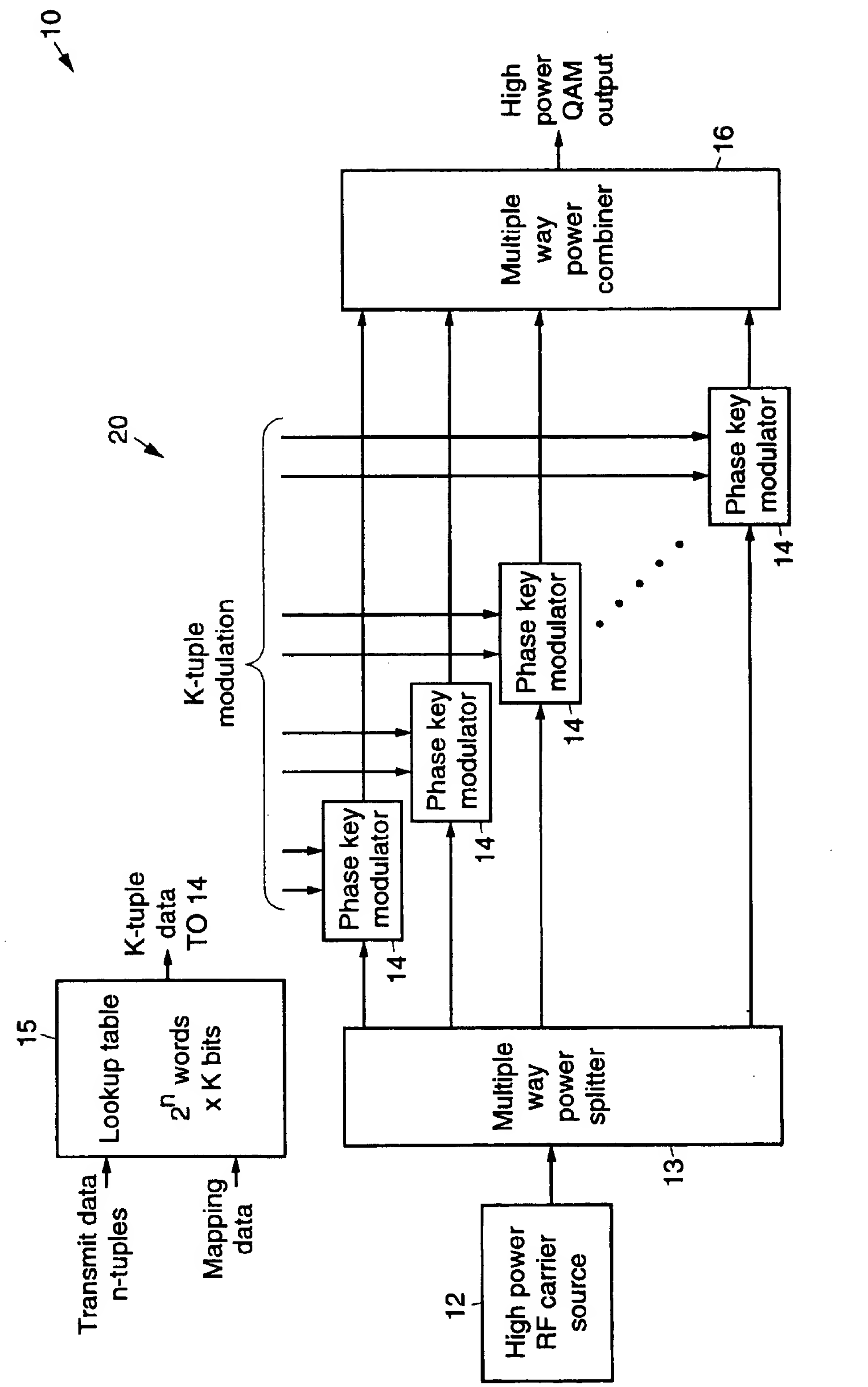
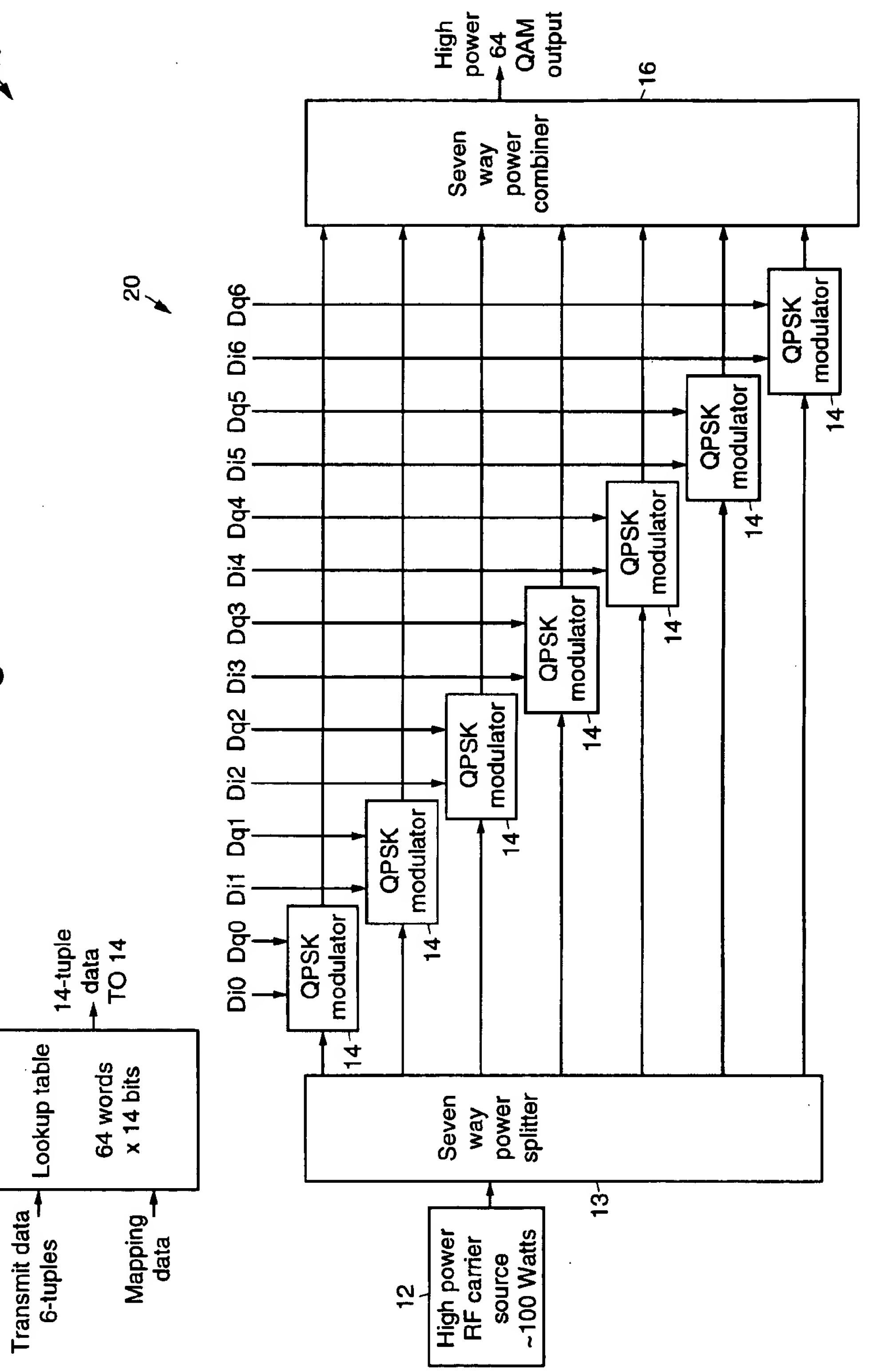

10
20
High power QAM output
16
Multiple way power combiner
K-tuple modulation
Phase key modulator
Phase key modulator
Phase key modulator
Phase key modulator
14
14
14
14
15
Lookup table
2^n words x K bits
K-tuple data TO 14
Transmit data n-tuples
Mapping data
Multiple way power splitter
13
12
High power RF carrier source

Fig. 2


10
20
High power 64 QAM output
16
Seven way power combiner
Dq6
Di6
Dq5
Di5
Dq4
Di4
Dq3
Di3
Dq2
Di2
Dq1
Di1
Dq0
Di0
QPSK modulator
14
14-tuple data TO 14
15
Lookup table
64 words x 14 bits
Transmit data 6-tuples
Mapping data
Seven way power splitter
13
12
High power RF carrier source ~100 Watts

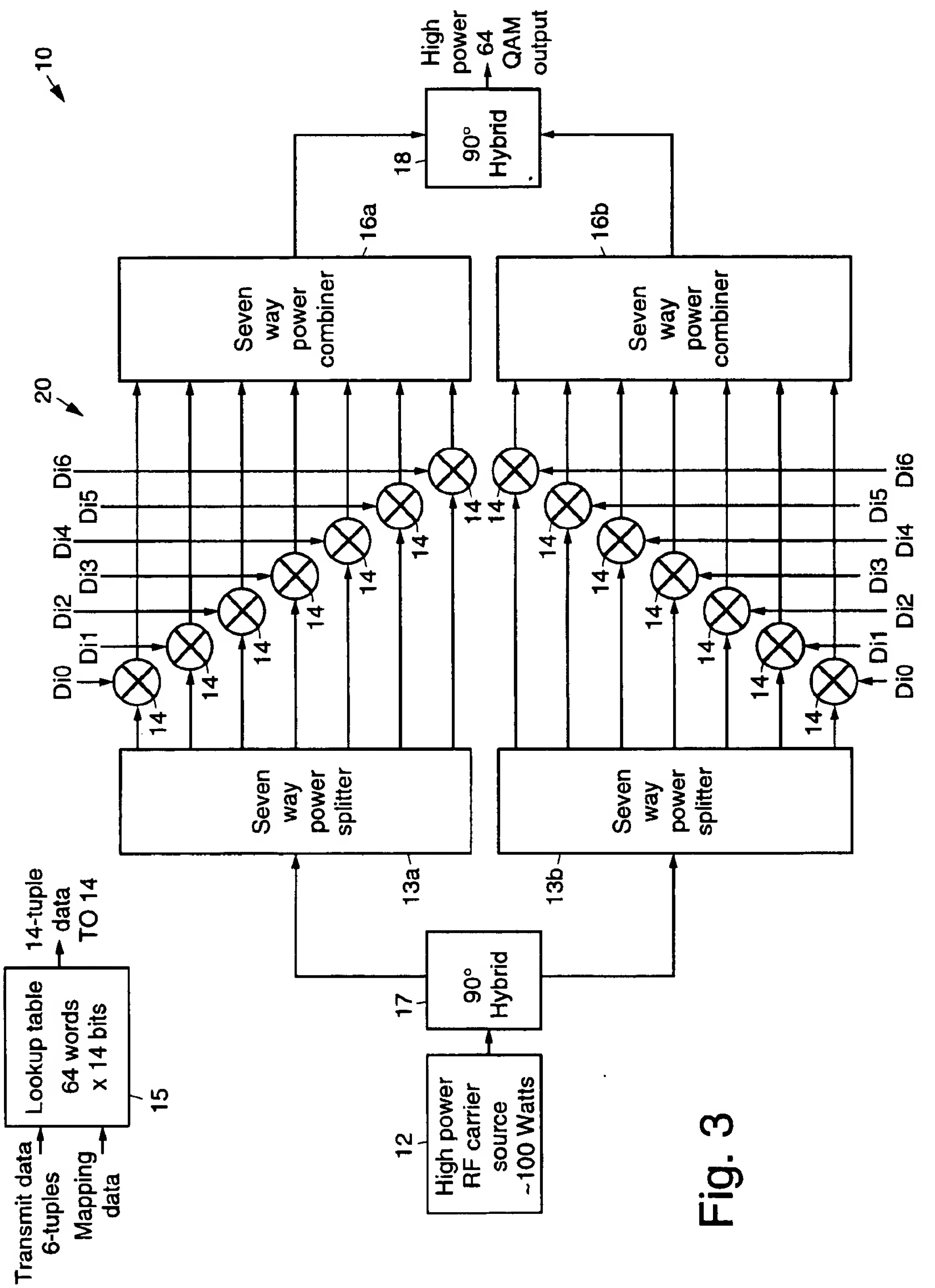

10
High power 64 QAM output
90° Hybrid
18
16a
16b
Seven way power combiner
Seven way power combiner
20
Di0
Di1
Di2
Di3
Di4
Di5
Di6
14
Seven way power splitter
Seven way power splitter
13a
13b
14-tuple data TO 14
Lookup table 64 words x 14 bits
15
Transmit data 6-tuples
Mapping data
90° Hybrid
17
High power RF carrier source ~100 Watts
12

Fig. 3

HIGH POWER TRANSMITTER EMPLOYING A HIGH POWER QAM MODULATOR

BACKGROUND

The present invention relates generally to RF transmitters, and more particularly, to improved high power RF transmitters employing high power QAM modulators.

For very high data rate and bandwidth efficient transmission, quadrature amplitude modulation (QAM) has become a major waveform option. Many modulator systems have been developed to perform quadrature amplitude modulation and compensate for bandpass distortion and nonlinear effects so that very high symbol rates (in excess of 1 Gsps) may be achieved. Conventional data modulation is performed at low power levels and sometimes at an intermediate frequency, and then frequency shifted and amplified to a suitable power level.

More recently, the assignee of the present invention has developed a modulating array transmitter which is disclosed in U.S. Pat. No. 5,612,651. This patent application teaches a method of combining the outputs of saturated power amplifier stages where each amplifier stage is driven by a QPSK modulator. The amplifier output signals are combined to form QAM high power signals. The invention disclosed in this patent application teaches that locating the modulation closer to the transmitting antenna reduces the number of distorting and performance-limiting elements of the transmitter.

Several patents were uncovered as a result of a computer search performed during the development of the present invention. U.S. Pat. No. 4,453,257 entitled "Spectrum Shaping Microwave Digital Modulators" spectral shaping of data NRZ (non-return to zero) waveforms with combined linear phase modulation methods as a substitute for phase keying modulation. This patent is not relevant to the present invention.

U.S. Pat. No. 4,835,493 entitled "Very Wideband Linear Amplitude Modulation of RF Signal by Vector Summation" discloses the use of linear phase modulators followed by high power amplifiers, but does not discuss the basic vector combining application to high rate QAM digital modulation. The focus of this patent relates to amplitude modulation wherein linear phase modulated signal components are used to achieve only linear amplitude modulation.

U.S. Pat. No. 5,329,259 entitled "Efficient Amplitude/Phase Modulation Amplifier" discloses a means of creating QAM signals by using two constant amplitude vectors. This patent discusses the use of QAM waveforms. However, this patent is not specifically relevant to the present invention.

Accordingly, it is an objective of the present invention to provide for improved high power RF transmitters employing high power QAM modulators.

SUMMARY OF THE INVENTION

To meet the above and other objectives, the present invention provides for a high power RF transmitter that uses a high power modulator that performs quadrature amplitude modulation (QAM) on a carrier signal after power amplification. While conventional data modulation is performed at low power levels and sometimes at an intermediate frequency, the present transmitter directly modulates a high power carrier signal.

The present invention comprises an RF carrier source that generates a high power RF carrier signal that is split by a power splitter. A lookup table containing 2^n words of K bits

receives transmit data and mapping data and generates K-tuple modulating data. A plurality of phase key modulators are respectively coupled to outputs of the power splitter and to the lookup table and phase key modulate each of the signal components of the carrier signal using the K-tuple modulating data. A power combiner is coupled to outputs of the phase key modulators for outputting a high power QAM constellation from the transmitter.

Binary phase shift keying (BPSK) modulators or quadrature phase shift keying (QPSK) modulators may be employed. The transmitter includes a plurality of power splitters, a plurality of power combiners, and a plurality of modulators along with input and output hybrids.

The present invention transposes the traditional locations of the modulator and power amplifier that performed in the RF carrier source. As a consequence, the present invention enables several economies of implementation and enhancements in performance, and enables the generation of very complex QAM signal constellations having very high precision.

BRIEF DESCRIPTION OF THE DRAWINGS

The various features and advantages of the present invention may be more readily understood with reference to the following detailed description taken in conjunction with the accompanying drawings, wherein like reference numerals represent like structural elements, and in which

FIG. 1 is a block diagram illustrating a basic high power transmitter employing a high power QAM modulator in accordance with the principles of the present invention;

FIG. 2 is a block diagram illustrating a high power transmitter employing a seven stage high power QAM modulator in accordance with the principles of the present invention using QPSK modulators; and

FIG. 3 is a block diagram illustrating a high power fourteen stage high power QAM transmitter in accordance with the principles of the present invention using bi-phase (BPSK) modulators.

DETAILED DESCRIPTION

Referring to the drawing figures, FIG. 1 is a block diagram illustrating a basic high power transmitter **10** employing a high power QAM modulator **20** in accordance with the principles of the present invention. The high power transmitter **10** is comprised of a high power RF carrier source **12** that is coupled to a multiple output power splitter **13**. The outputs of the power splitter are respectively coupled to a plurality of phase key modulators **14** that make up the high power QAM modulator **20**. The phase key modulators **14** comprise low loss, high power modulators **14**. A lookup table ~~15 containing~~ 2^B words by K bits is provided. Transmit data (having n-tuples) that are to be transmitted are supplied to the lookup table **15** along with mapping data that maps the transmit data to the stored words in the lookup table **15**, and which generates K-tuple modulating data that are supplied to the phase key modulators **14**. Outputs of the phase key modulators **14** are coupled to a multiple input power combiner **16** which outputs a high power QAM constellation from the transmitter **10**.

In operation, a high power carrier signal is split into a predetermined number of equal power signal paths. Each signal component is individually phase key modulated using the low loss, high power phase key modulator **14** in each path, using either binary phase shift keying (BPSK) or quadrature phase shift keying (QPSK) modulation, for

example. The respective outputs of the phase key modulators **14** are then combined in the power combiner **16** to produce a transmitter signal output.

Two preferred embodiments for implementing 64 QAM transmitters **10** are shown in FIGS. **2** and **3**. More specifically, FIG. **2** is a block diagram illustrating a high power transmitter employing a seven stage high power QAM modulator that uses QPSK modulators. FIG. **3** is a block diagram illustrating a high power fourteen stage high power QAM transmitter that uses bi-phase modulators. A 64 QAM transmitter **10** requires 7 QPSK modulators **14**, while a 256 QAM transmitter **10** requires 15 QPSK modulators **14**.

Referring to FIG. **2**, 6-tuple transmit data is supplied to the lookup table **15** which contains 64 words by 14 bits. The output of the lookup table **15** is 14-tuple modulating data (Di0 . . . Di6, Dq0 . . . Dq6) that are supplied to the modulators **14**. The high power RF source **12** has an output power on the order of 100 Watts, and produces a high power carrier signal that is input to a seven way power splitter **13**. Outputs of the seven way power splitter **13** are coupled to seven QPSK modulators **14** along with the modulating data from the lookup table **15**. The high power carrier signal supplied by the high power RF source **12** is QPSK modulated in each of the modulators **14** using the modulating data from the lookup table **15**. A seven way power combiner **16** combines the outputs of each of the modulators **14** to produce a 64 QAM constellation that is output from the transmitter **10**.

Referring to FIG. **3**, high power carrier signal generated by the high power (100 Watt) RF source **12** is coupled to a 90° hybrid **17** which splits the carrier signal along two paths which are 90° out of phase with respect to each other. Each of the paths carries about 50 Watts of power. The split carrier signal is supplied to two seven way power splitters **13***a*, **13***b* which separately distribute the split carrier signal to first inputs of seven bi-phase modulators **14** or mixers **14**. 6-tuple transmit data is supplied to the lookup table **15** which contains 64 words by 14 bits. The output of the lookup table **15** is 14-tuple modulating data (Di0 . . . Di6, Dq0 . . . Dq6) that are supplied to respective second inputs of the individual bi-phase modulators **14**.

The high power carrier signal supplied by the high power RF source **12** is modulated in each of the bi-phase modulators **14** using the 14-tuple modulating data from the lookup table **15**. Two seven way power combiners **16***a*, **16***b* combines the outputs of the respective sets of modulators **14***a*, **14***b*. The respective combined outputs of the seven way power combiners **16***a*, **16***b* are combined using a 0° hybrid **18** to produce a 64 QAM constellation that is output from the transmitter **10**.

There are many ways to generate high levels of RF carrier power with high efficiency. Tens to hundreds of Watts of power over a large range of the microwave and millimeter wave spectrum may be generated using Gunn diode oscillators, for example. Orders of magnitude high power may be generated using Klystrons and Magnetrons, or other similar devices. The power is preferentially generated by a narrow band device, thus avoiding the necessity for wideband amplifier systems such as traveling wave tube amplifiers (TWTAs).

The use of QPSK or BPSK modulators **14** in the transmitters **10** depends on a number of design requirements such as the complexity of the QAM constellation that is generated, the power limitations of the switching devices of the phase key modulators **14**, and the required number of redundant stages needed to implement a failure-robust system, for example, such as may be designed for space applications. The QAM constellation may be formed in the manner described in the above-cited patent application entitled "Modulating Array Transmitter".

Thus, improved high power RF transmitters employing high power QAM modulators have been disclosed. It is to be understood that the described embodiments are merely illustrative of some of the many specific embodiments which represent applications of the principles of the present invention. Clearly, numerous and other arrangements can be readily devised by those skilled in the art without departing from the scope of the invention.

What is claimed is:

1. A high power transmitter comprising:

a high power RF carrier source for generating a high power RF carrier signal;

a multiple output power splitter coupled to the high power RF carrier source;

a lookup table containing 2^B words by K bits for receiving n-tuple transmit data that is to be transmitted and mapping data that maps the transmit data to the stored words in the lookup table, for generating K-tuple modulating data;

a plurality of phase key modulators that are respectively coupled to each of the outputs of the power splitter and to the lookup table for phase key modulating each of the signal components of the carrier signal using the K-tuple modulating data supplied by the lookup table; and

a multiple input power combiner coupled to outputs of the phase key modulators for outputting a high power QAM constellation from the transmitter.

2. The transmitter of claim **1** wherein the plurality of phase key modulators each comprise binary phase shift keying modulators.

3. The transmitter of claim **2** wherein the plurality of phase key modulators each comprise quadrature phase shift keying modulators.

4. The transmitter of claim **1** wherein 6-tuple transmit data is supplied to the lookup table which contains 64 words by 14 bits, the lookup table outputs 14-tuple modulating data that are supplied to the modulators, the power splitter comprises a seven way power splitter whose outputs are coupled to seven QPSK modulators, and the power combiner comprises a seven way power combiner that combines the outputs of each of the modulators to produce a 64 QAM constellation that is output from the transmitter.

5. The transmitter of claim **1** further comprising:

a 90° hybrid **1** for splitting the carrier signal along two paths;

and wherein the power splitter comprises two seven way power splitters respectively disposed along the two paths that separately distribute the split carrier signal;

and wherein the split carrier signals are coupled by the two seven way power splitters to first inputs of two sets of seven bi-phase modulators;

and wherein the lookup table contains 64 words by 14 bits, and whose output is 14-tuple modulating data that are supplied to respective second inputs of the bi-phase modulators;

and wherein the power combiner comprises two seven way power combiners that combine the outputs of the respective sets of modulators;

and wherein the transmitter further comprises a 0° hybrid coupled to the seven way power combiners for com-

bining the respective outputs thereof to produce a 64 QAM constellation that is output from the transmitter.

6. A high power transmitter comprising:

a high power RF carrier source for generating a high power RF carrier signal;

a seven way power splitter coupled to the high power RF carrier source;

a lookup table containing 64 words by 14 bits for receiving 6-tuple transmit data that is to be transmitted and mapping data that maps the transmit data to the stored words in the lookup table, for generating 14-tuple modulating data;

a plurality of phase key modulators that are respectively coupled to each of the outputs of the power splitter and to the lookup table for phase key modulating each of the signal components of the carrier signal using the K-tuple modulating data supplied by the lookup table; and

a seven way power combiner coupled to outputs of the phase key modulators for outputting a high power 64 QAM constellation from the transmitter.

7. The transmitter of claim 6 wherein the plurality of phase key modulators each comprise quadrature phase shift keying modulators.

8. A high power transmitter comprising:

a high power RF carrier source for generating a high power RF carrier signal;

a 90° hybrid for splitting the carrier signal along two paths;

two seven way power splitters coupled to the 90° hybrid and respectively disposed along the two paths that separately distribute the split carrier signal;

a lookup table containing 64 words by 14 bits for receiving 6-tuple transmit data that is to be transmitted and mapping data that maps the transmit data to the stored words in the lookup table, for generating 14-tuple modulating data;

a plurality of sets of bi-phase modulators respectively coupled to each of the outputs of the power splitters and to the lookup table for phase key modulating each of the signal components of the split carrier signal using the 14-tuple modulating data supplied by the lookup table; and

two seven way power combiners coupled to outputs of the respective sets of modulators that combine the outputs of the respective sets of modulators; and

a 0° hybrid coupled to the seven way power combiners for combining the respective outputs thereof to produce a 64 QAM constellation that is output from the transmitter.

* * * * *